OPTIMIZED MODELS OF MODES CHOICE FOR DISPLACEMENT OF TECHNICAL SYSTEMS OBJECTS

Zhak S.V., Rostov University,
Rostov-on-Don,Russia
Sidorenko V.S.,Don Technical University,
Rostov-on-Don,Russia

The working processes which are carried out by the technological machines, as a rule require the shifts of different objects from one set point to another, and more effectively they are realized by means of positional hydro-mechanical systems (PHMS).

The choice of the best PHMS type requires their comparison when the optimum regimes of shifting are used, i.e. the constructing and analysis of optimization models of projected system, complicated by non-linearness of the equals and by the existence at least two criterions of optimality such as speed and accuracy of the positioning.

In such method it is possible to create the universal programming realizations of models for personal computers, to decrease spendings of time and resources for their development and improving of new technical decisions.

In that case the object of investigation is the total hydro-mechanical system of programmed steering, which is covering the different methods of structure-parametric steering of positional machine's shifts. Such PHMS is the complex combined technical system, including multy-mass mechanical (MMS), power hydraulic (HPS) and steering electro-hydraulic (SS) subsystem.

The complete mathematical model of summarized PHMS is described by the system of non-linear differential equals.

The equal of mechanical subsystem:

$$\frac{d^2 z_1}{dt^2} = -a_1 \frac{dz_1}{dt} - a_2 z_1 - b_1 + U_1 + b_2 \frac{dz_2}{dt} - C_1 \varphi(z_1 - z_2) \qquad (1)$$

$$\frac{d^2 z_2}{dt^2} = -b_3 - a_3 \frac{dz_2}{dt} - a_4 z_2 + b_4 \frac{dz_1}{dt} + C_2 \varphi(z_1 - z_2) - U_2 \qquad (2)$$

Function $\varphi(y)=0$ if $|y|<\delta/2$, $\varphi(y)=y \pm \delta/2$ if $|y|>\delta/2$, $(y=z_1-z_2)$ considers the effect of gap δ in mechanical subsystem.

The equal of hydraulic power subsystem is based on the equals of liquid using balance and Bernoulli.

$$\frac{dp}{dt} = -a_5 \frac{dz_1}{dt} - a_6 p + a_7 (x_0 - x)\sqrt{p_H - p}, \qquad (3)$$

where $p = p_1 - p_2$

The equal of steering device (SS).

$$\frac{d^2 x}{dt^2} = -b_5 \frac{dx}{dt} - b_6 x + U_3 \qquad (4)$$

a_i , b_j - coefficients depending on constructive factors of PHMS and power effects character, etc.

Two first equals (1), (2) suit state variables Z_1, Z_2 of two-mass resilient dynamic system. The equal (3) describes the changing of pressure difference at the input P_1 and outcome - P_2 of hydroengine by means of choker steering by working liquid currents with steering effect X. The law of steering effect's changing X(T) is described by equal (4).

Steering U_3 is formed by the original hydro-mechanical sensor of state by scheme of variables' conjunction of set Z_3 and factual Z_2 moments of measuring of basic steerings U_1, U_2 in equals (1) and (2). The steering of shifts is produced by scheme:

$$U \to x \to U_1, U_2 \to z_1, \frac{dz_1}{dt}, z_2, \frac{dz_2}{dt}$$

At the following inceptive conditions

$$t = 0, \; z_1(0) = z_1^0, \; \frac{dz_1}{dt} = 0, \; z_2(0) = z_2^0, \; \frac{dz_2}{dt} = 0;$$

$$t = T, \; z_1(1) = 0, \; \frac{dz_1}{dt} = 0, \; z_2(1) = 0, \; \frac{dz_2}{dt} = 0 .$$

and requests for target function T-min, Z(T)-min we come to two-criterial non-linear problem of optimum speed.

Because of bulkiness and complexity of equals (1)...(4) there appeared the necessity of simplification and decomposition of total mathematical model on the consecution of gradually complicated problems from two-measured liner to nine-measured non-linear:

1. The most simple model of PHMS is shaped by means of it's adduction to one-mass dynamic system. In that case it is described by equal (5)

$$\frac{d^2 z_1}{dt^2} = -a_8 \frac{dz_1}{dt} - a_9 z_1 + U \qquad (5)$$

The choice of concrete ways of steering U accounts' realization is ignored there, i.e. the analysis of equals (2), (3), (4) isn't produced there, but it is changed on antecedent forming of extreme steering accounts.

In such setting it was investigated the two-measured linear problem of optimum speed with preservation of scrap-linear function in equal (5). There was reached clear analytic solution which made possible to built equals for the switching moment tp and minimal time of shift T-min. For effectivenes's appreciation of suggested solution the model's investigation had been done by Neighshtedt's method. At comparison there was achieved good analogy between the results of experiment.

At link steering:

$$
\begin{aligned}
&Umax=K_{hd}(P1max-P2min) - a_0 && \text{(where } 0<t<tp\text{)} \\
&Umin=K_{hd}(P1min-P2max) - a_0 - eF_3 && \text{(where } 0<t<T\text{)}
\end{aligned} \tag{6}
$$

where K_{hd} - basic constructive parameter of hydro-engine, P1, P2 - pressures at input and outcome of hydro-engine, F_3 - inhibitory force, a_0 - the resistance forces, e - Boolean parameter determining the existence of damper.

The noticeable approaching to real conditions gives link-approximated steering *Uêð* with exponential increasing or decreasing of it's account in moments of

$$
\begin{aligned}
&\text{acceleration} \quad U_{KP} = U_{\max}(1 - e^{-\alpha_1 t_e}) \\
&\text{damping} \quad U_{KP} = U_{\max} + (U_{\min} - U_{\max})(1 - e^{-\alpha_2 t_e})
\end{aligned} \tag{7}
$$

where α_1,α_2 - coefficients, t_e -time of pressure drop changing P on hydro-engine until extremal account which is determined by the experiment.

2.The second stage of simplified PHMS model considers it's MPS as resilient two-mass dynamic system, which is described by equals (1) and (2). At link (6) or quasi-link (7) steering there is discussed four-measured puzzle with scrap-linear function preservation. It was shown by the model's investigation that introduction of n-measured space can lead to several moments of switching. In given class of PHMS the main feature is behaving of piloted masses of shifting object with state variables Z2, $\frac{dz_2}{dt^2}$, that makes possible one switch of steering.

3. Introduction in simplified models 1 and 2 of hydraulic power subsystem for example with link steering by the liquid currents (equal 3), which describes non-linear changing of pressures P1, P2, leads to their noticeable complication. There is equal (4) is

ignored. This equal forms the steering effect X. It is realized by means of link (0 or X_0) or quasi-link on experimental data.

4. The complete mathematical model of summarized PHMS covers nine-measured non-linearsystem of equals (1)...(4). At it's investigation it was solved the Cauchy's problem by Runge-Kutta's method for different moments of switching. The anticipatory mark of value tp was made by means ofinvestigation and analysis of simplified models 1, 2. It made possible at the original data to chose such value tp, which would answer to concrete accuracy of positioning with the fixation of achieved hangs of time and shifts' accuracy. On these accounts there was stood out the multiple of Pareto of two-criterial problem and there was achieved the better result in dialogue with person ,who was taking the decision on the base of formed principle of optimization.

The calculating procedures which are advanced for models 1...4 make possibility to determine optimum steering U_1 and U_2, the quantity and coordinates of switching moments of steering and characteristics of steering devices. As the example there is given in the table the results of investigation of rotary hydro-table with hydraulic damping device (variant 1) and with hydro-mechanical steering damping (variant 2) at rotation on $Z_3=2\pi$. The real regime of work had a limitation of speed and was considered as suboptimum.

Table

Operating condition	Variant PHMS	Z3 rad.	T s	Z(T) pad
real	I	2π	0.456	0.0073
	II		0.449	0.0061
optimum	I		0.248	0.0052
	II		0.162	0.0038

As it is following from the table at optimum steering speed and accuracy of positioning increase to a large extend (speed: for I- in 1.85, for II- in 2.8 times; accuracy: approximately into 1.5 times).

The results of computing experiment give us good analogy with natural experiments' data, that proves adequacy of suggested models with investigated processes. The analysis of solutions for the complete model gives us an opportunity to give not only explanation of optimum-speed PHMS, but to investigate the affluence of their constructive parameters on speed and accuracy, to appreciate the effectiveness of various structure-parametric steering methods , the changing of phase trajectories at real switch of steering, to think over the heuristic methods of correcting of switch-point in inclinations of steering from nominal and to compare the total problem's solutions with solution of simplified models of PHMS.

The investigations of optimizational models give us a possibility to determine the basic methods of optimum PHMS projecting:

- structure-parametric steering of positional cycles;

- making multy-functional devices with hydraulic lines of communication;
- adaptation of steering subsystem of PHMS to variable external effects.

The results of work were realized in various supply, transporting and orientating mechanisms.

<u>Reference.</u>

1. Sidorenko V.S., Zhak S.V., Kluzhev O.V. «Optimization of supply hydro-mechanical systems on the base of methods of optimum steering.» Collection of scientific works «Hydro-systems of technological and mobile machines.» DSTU, Rostov-on-Don, 1995, C 1-14.
2. Boltyansky V.G. «The mathematical methods of optimum steering.» M. «Science», 1969, 238ps.